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Design and testing of secondary mirrors for the core CXRS diagnostic system in ITER

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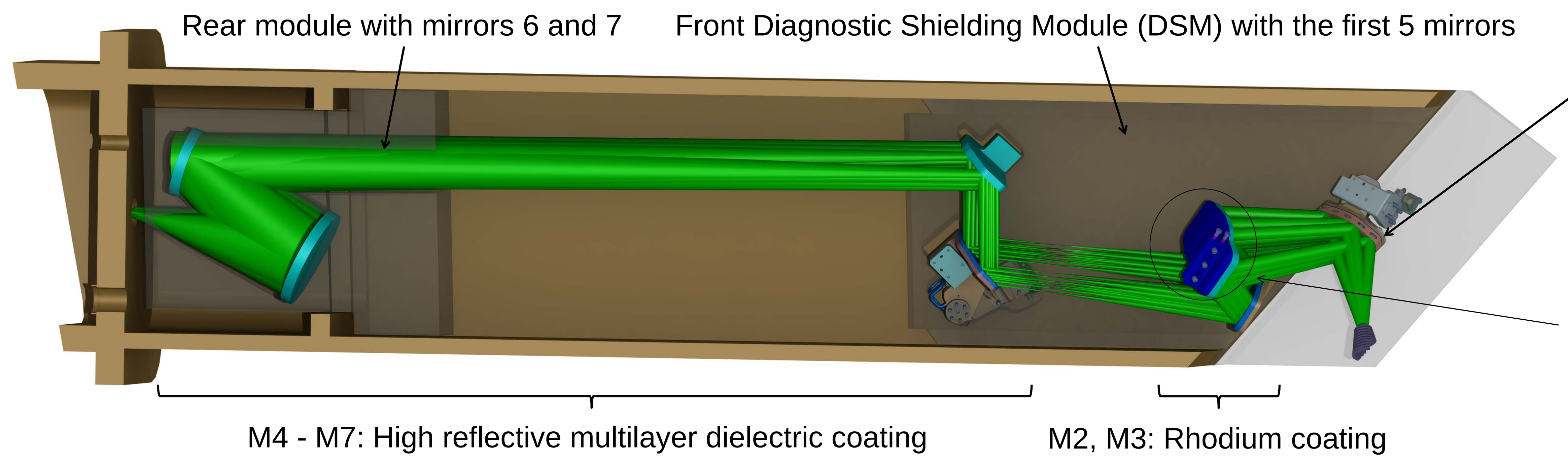
1. Optical system in the ITER upper port plug #3 for core CXRS and BES

SS316L(N)-IG is investigated as structural material for all secondary mirrors
- Eliminate interfaces with dissimilar coefficient of thermal expansion
- Passive athermal design at uniform system temperature
- Simplifies temperature control with water
- Well established manufacturing possibilities

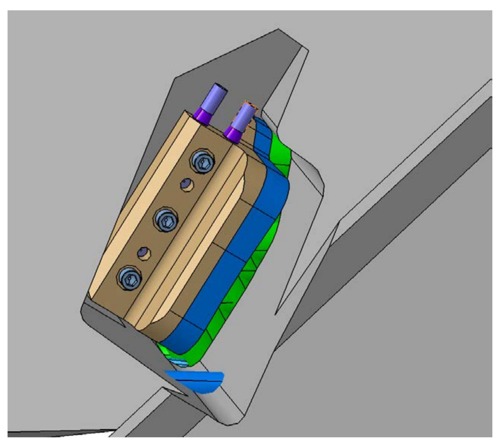
Drawback: Low thermal stability. Thermal control is required.

Table 1: Wavelength of interest for core CXRS and BES

Wavelength band [nm]	Accessible spectral lines
460.8 to 473.6	He II; Be IV
518.9 to 533.1	C VI; Ne X; Ar XVII
649.0 to 663.0	Hα (BES)



First mirror:
- Single crystalline Molybdenum substrate
- Not coated

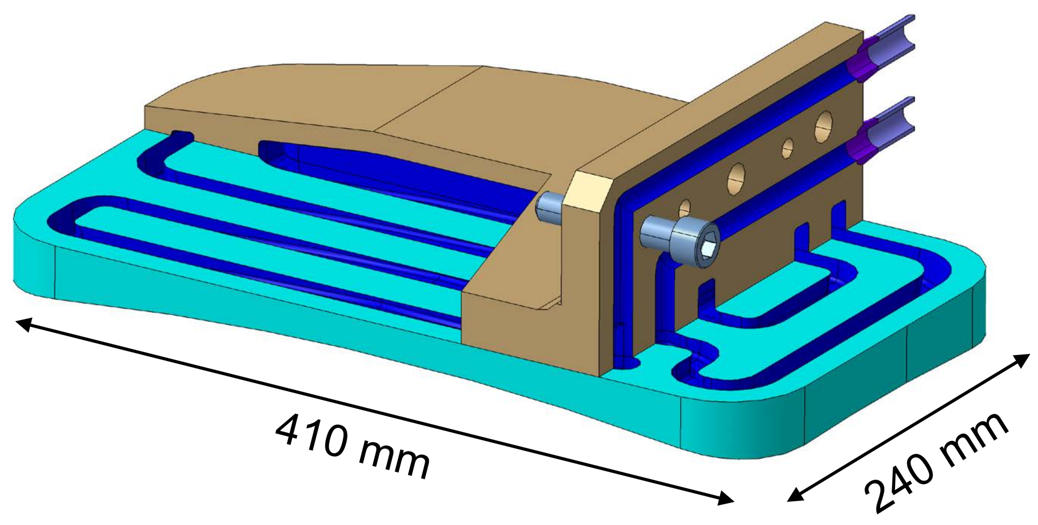

M2 mounted in the DSM

Secondary mirrors are mounted from the outside of the modules. Maintenance by remote handling is possible after removal from the UPP shell.

2. Mechanical design of the secondary mirrors

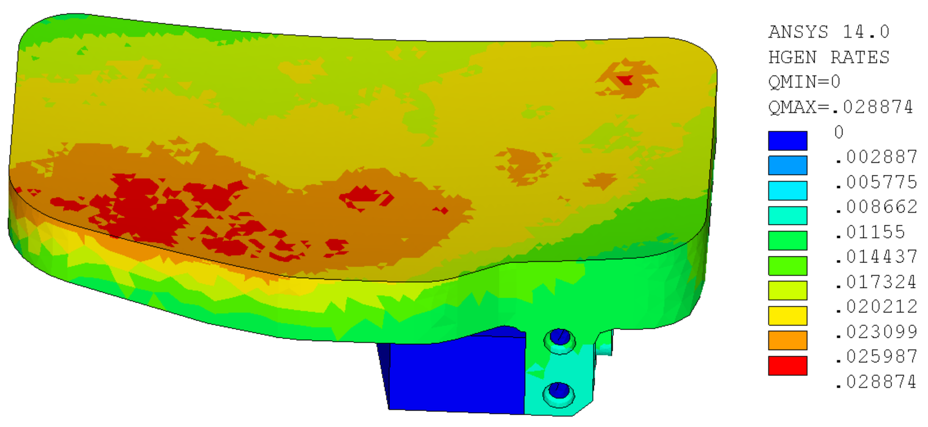
Goals of the design
- Minimise temperature gradients
- Compact design for RH maintenance
- Stable and robust system

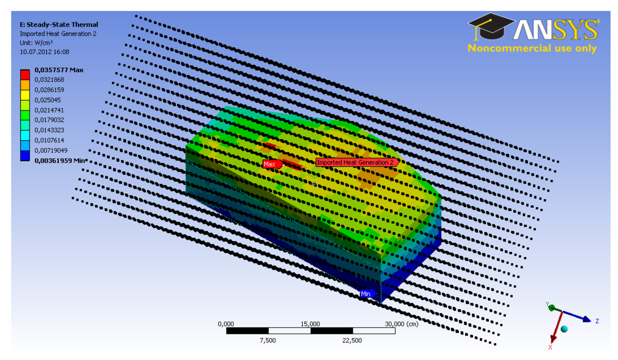
Assembly of the two parts is planned by diffusion welding.



Cooling channel inside the M2 substrate and mounting flange.

Simulation includes:
- Bolt pre-load
- Cooling and heating by internal water at 4.8 MPa pressure
- Local neutron and gamma heating
- Radiative surface heating
- Other operational loads



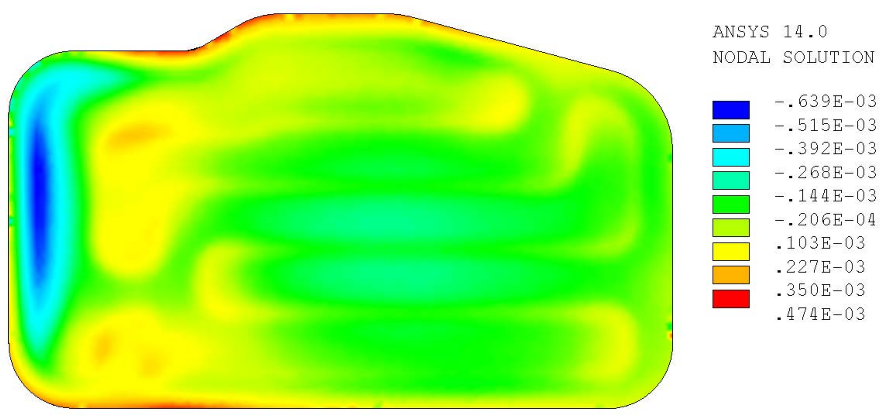


Local heating imported from MCNP meshed volume

	Rx [mrad]	Ry [mrad]	Defocus [µm]	Remaining [µm]
Tolerance	±1.31	±1.31	± 31.6	± 31.6
500 MW DT	-2.89E-2	5.8E-3	-24.7	1.11
100°C to 70°C (50s)	6.51E-3	-4.34E-3	-18.4	7.04

Table 2: Thermo-mechanical results of M2

- 500 MW DT-operation results in a ΔT of 0.74°C on the substrate (steady state)
- Sudden drop in feed water temperature (100°C to 70°C) increases higher order surface distortion with a maximum at 50s.



Remaining change in sag: M2 500 MW DT steady state

Conclusions

- The mirror from SS316L(N) substrate is within the preliminary tolerances.
- Deformation from internal pressure should to be addressed.
- Local heating differences have only a small impact on stability.
- First calculations show reasonable stability against feed water temperature changes.

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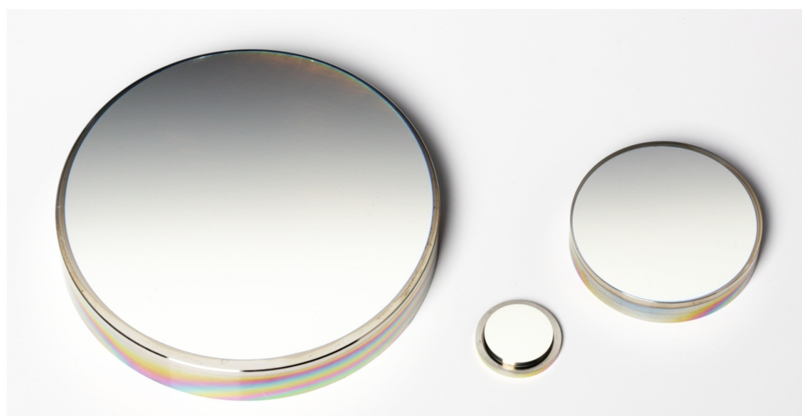
3. Testing of multilayer dielectric coating on stainless steel

Prototypes with TiO_2 / SiO_3-coating
- Uniform layer structure
- Number of layers limited
- Know-how on Aluminium
- Experience up to 200°C

The coating consists of 64 λ/4 layers arranged in three groups, minimising internal stress.

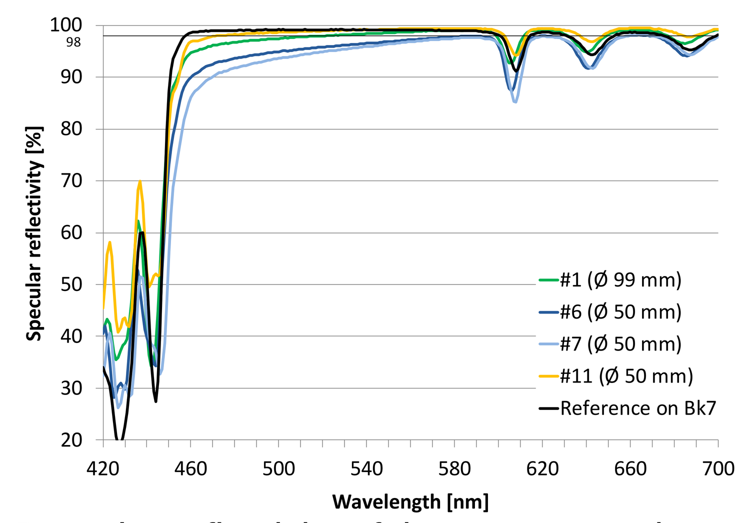

TiO_2/SiO_3 coating on 1.4420 stainless steel

Sample	Ø [mm]	Ra [nm]	Rz [nm]	R [%]
1	99	2.6 (0.5)	27.2 (9.1)	97.34
6	50	3.6 (0.2)	32.7 (2.6)	95.41
7	50	2.6 (0.7)	35.3 (13.9)	94.9
11	50	4.5 (0.2)	39.4 (4.0)	97.94

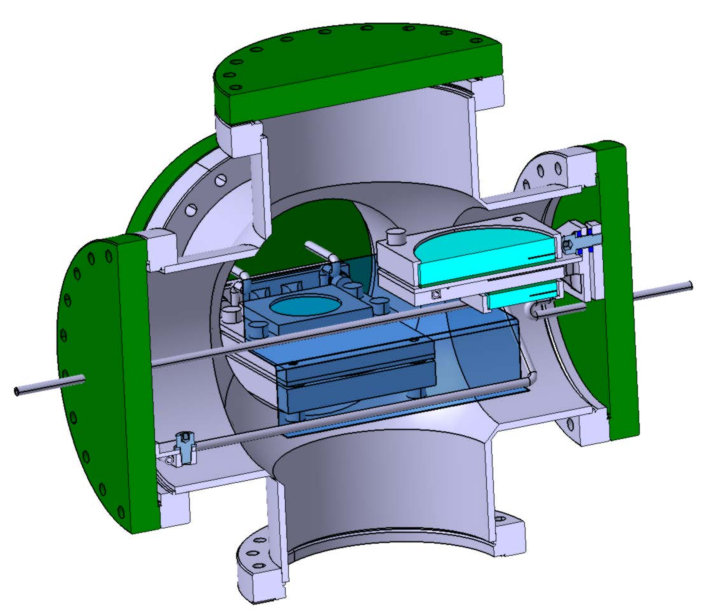
Table 3: Roughness and reflectivity of selected mirrors

Initial testing gave good adhesion for all tested combinations: 1.4429 with
- SiO_2 (50 and 80 nm)
- Cr (30 nm)
- 80 / 20 mixture SiO_2 / Cr
- TiO_2 (73 nm)

Testing under preparation:
- Long term behaviour at elevated temperature
- Resistance to H_2O atmosphere
- Thermal shock



Specular reflectivity of the prototype mirrors


Vacuum chamber for thermal testing.

Conclusions

- Adhesion on 1.4429 seems good
- Reflectivity of >98% possible on stainless steel
- Polishing of substrate needs additional investigation

Acknowledgments

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